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Assessing the Performance of SWAT and AnnAGNPS Models in a Coastal Plain Watershed, Choptank River, Maryland, U.S.A.

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***Abstract*.** This study was conducted under the USDA-Conservation Effects Assessment Project (CEAP) on the Choptank River watershed which is located within the Chesapeake Bay watershed on the Delmarva Peninsula in Maryland, U.S.A. The watershed is nearly 1036 km^2 and is dominated primarily by corn and soybean production with extensive poultry production operations. Portions of the watershed have been identified as "impaired waters" under Section 303(d) of the Federal Clean Water Act due to high levels of nutrients and sediment. In recent years, a significant number of state and federal incentive programs have been implemented for water quality improvement in this watershed, but environmental benefits from these programs have never been quantified. Two of the most widely used USDA watershed-scale models, Soil and Water Assessment Tool (SWAT) and Annualized Agricultural Non-Point Source (AnnAGNPS) were applied to quantify the environmental benefits widely used practices like winter cover crops. Five years (1991-1995) of detailed observed flow and water quality data were used to provide baseline calibration and validation for the two models. Simulation results showed significant differences in base-flow estimations for the two models. This difference may be considered to be a significant factor in model selection to estimate nutrients and sediment loads in regions of fairly flat landscapes such as the Coastal Plain physiographic region. This study concluded that both SWAT and AnnAGNPS models performed well for simulating hydrologic conditions, however, for nitrate loads, AnnAGNPS NC coefficients were relatively lower, slightly above an acceptable 0.5 value.

Keywords. Conservation Effects Assessment Project (CEAP), Chesapeake Bay, Soil and Water Assessment Tool (SWAT), Annualized Agricultural Non-Point Source (AnnAGNPS), Non-Point Source.

Introduction

Resource managers, extension agents, and producers require reliable tools for evaluating the effectiveness of conservation measures applied as part of a comprehensive resource management plan (Shirmohammadi and Knisel, 1994). Do the environmental benefits of a particular practice in qualitative terms justify the cost of implementation, maintenance and incentive payments? When conservation practices are implemented on a watershed scale, how can the benefits be observed? If the goal is improved water quality, a well-designed monitoring program is extremely effective. However, monitoring over long time periods to capture the climatic variability is costly. A more useful approach is to combine monitoring with watershed water quality modeling to allow the examination of climate effects along with variability in land use, soils, and management practices (Shirmohammadi et al., 2001).

Water quality models were developed to evaluate the hydrologic and water quality responses of agricultural watersheds at different scales. CREAMS (Chemical, Runoff, and Erosion from Agricultural management Systems) model was developed by a team of ARS scientists in 1970s (Knisel, 1980). Then, other models such as GLEAMS (Groundwater Loading Effects of Agricultural Management Systems; Leonard, et al., 1987), EPIC (Erosion Production Impact Calculator; Williams et al., 1985), and others followed. The main objective of all these models has been to provide a management tool to examine the long term impacts of agricultural activities on water quality. The models are first “calibrated” against some historical available data collected from within the study watershed. The calibrated model can then used to simulate other time periods, or it can be used to examine best management practice (BMP) implementation combinations in space and time. A major goal in utilizing water quality models has been to gain an appreciation for the magnitude of changes in pollutant loadings resulting from implementation of a particular conservation practice(s). Water quality models don’t actually provide absolute “water quality” information, instead, they provide an estimate of pollutant loads delivered to the edge of a field or to some point in a watershed. These comparative analyses allow the modeler to evaluate the effect of implementing a particular practice or combination of practices compared to the present or baseline conditions. In addition, the accuracy of the model results will directly reflect the quantity and appropriateness of the input data, as more data is used to reflect the field situation/scenarios, the better the simulated results are expected to be.

The two well-known watershed-scale models chosen for this evaluation were the Soil & Water Assessment Tool (SWAT) and Annualized Agriculture Non-Point Source Pollution Simulation (AnnAGNPS). Both of these models are being presently suggested by the U.S. Department of Agriculture (USDA), Agricultural Research Service (ARS) and the USDA Natural Resource Conservation Service (NRCS) to be used in CEAP. SWAT is a continuous simulation model using Hydrologic Response Unit (HRU) concept within sub-watershed areas, as the basis for representing the watershed. AnnAGNPS utilizes cells as the basis for model simulations.

Methodology

1. Site Characteristics:

The study site (German Branch watershed, a sub-watershed of the Choptank River basin) is located on the Delmarva Peninsula in Maryland, and covers approximately 5000 ha of the greater Choptank River Basin, located within the larger Chesapeake Bay watershed in U.S.A. (Fig. 1). The German Branch was selected for this model evaluation since it is one of 15 non-tidal sub-basins within the Choptank (tidal/non-tidal) watershed, currently being evaluated under the overall CEAP objectives. The climate in this region is mostly humid with an annual average rainfall of 110 cm that is fairly evenly distributed over time. Average monthly temperatures range from 2 C in January/February and up to 25 C in July/August with a yearly average of 12.83 C. Soils in the Choptank are underlain by the Columbia aquifer that has an almost continuous aquifer. Surface sediments are the re-worked sands, clays, and gravels of the Talbot and Wicomico formations (Hamilton et al., 1993). Upland soils within the German Branch are dominated by Ingleside sandy loam on 2-5% slopes. The poultry industry has grown in the area, with 27 farms residing in the county housing over 1.7 million birds in 1992. In 2002, that number jumped to 44 farms and over 8.5 million birds.

A comprehensive land use, water quality and water discharge group of datasets are available for this watershed. German Branch was the subject of an intensive monitoring campaign from 1991-1995 in a study conducted by the Maryland Department of Natural Resources (Jordan report). The high quality of the datasets and the dominance of agricultural land use in the watershed make the German Branch an excellent opportunity for model calibration.

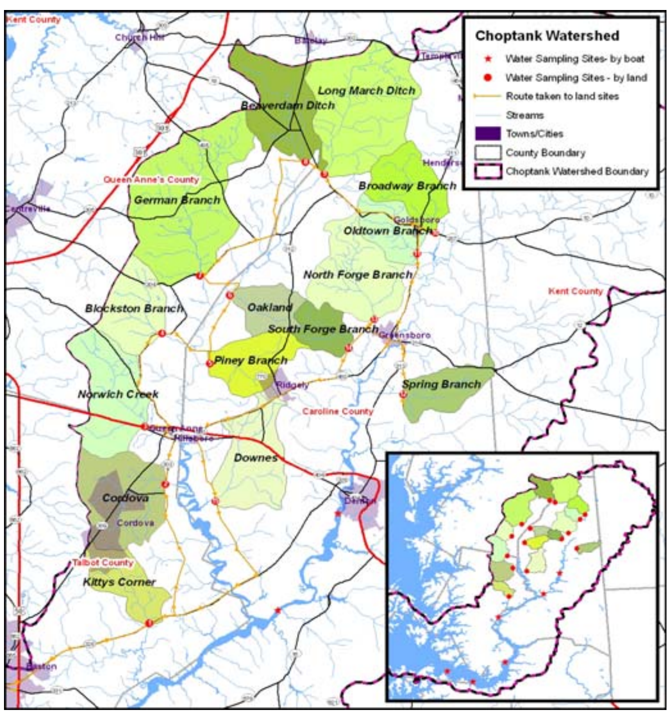


Figure 1. Fifteen selected sub-watersheds within the Choptank watershed.

2. Model Characteristics:

SWAT:

This model was developed based on the strengths of two previous models, SWRRB (Simulator for Water Resources in Rural Basins, Williams et al., 1985) and GLEAMS (Groundwater Loading Effects of Agricultural Management Systems, Leonard et al., 1987). The model simulates eight major components: hydrology, weather, sedimentation, soil temperature, crop growth, nutrients, pesticides, and agricultural management (Neitsch et al., 2002). Major hydrologic processes that can be simulated by the model include ET, surface runoff, infiltration, percolation, shallow and deep aquifer flows, and channel routing (Arnold et al., 1998). Streamflow in the main channel is determined by three sources: surface runoff, lateral flow, and base flow from shallow aquifers. Watershed is first divided into sub-watersheds, based on drainage areas of the tributaries, and each sub-watershed then is further divided into HRUs (Hydrologic Response Units) by superimposing land cover and soil type within each given sub-watershed. Model simulations perform on HRU level.

AnnAGNPS:

This model (http://www.sedlab.olemiss.edu/AGNPS.html) is also a continuous and daily simulator similar to the SWAT model and considers basic components such as hydrology, sediment, nutrient, and pesticide transport. The difference between these two modes is in model structure. Instead of using HRUs in the SWAT model, AnnAGNPS designates cells of various sizes and the pollutants are routed from these cells into the associated reaches, and finally, either deposit the pollutants within the stream channel system or transport them out of the watershed. This structural approach allows for simulations of the specific management practices that are very site-specific. AnnAGNPS, like SWAT also uses SCS curve number technique to generate daily runoff (Geter and Theurer, 1998).

Our current modeling efforts, as explained earlier, are focused on the German Branch watershed, where there is a record of water quality pre- and post- BMP implementation. The majority of the BMPs implemented in the watershed from 1991-1995 were cover crops and CREP sponsored buffers. In the process of model calibration, attempts were made to keep the land use and management schedules at similar percentages and timeframes that were derived from the National Agricultural Statistics Service (NASS) data for the period of simulation.

3. Data Preparation for Models:

Although there are some differences in model input requirements between the two models, the three basic common model input information include the digital elevation model (DEM), land cover, and soil type. Both models also need other critical input parameters such as weather data and agronomic management information. The DEM based on the USGS 30 m resolution is currently the base for all derived topographic information (website or reference?) and the initiation of model structure that dictates flow pathways. The soil dataset used was the Soil Survey Geographic database (SSURGO), which was obtained from the NRCS Soils Data Mart.

For SWAT, the watershed was delineated into total of thirty three sub-basins and 118 HRUs. The agricultural HRU has been given a specific agricultural rotation, namely some permutation on corn/wheat/soybean with management in each HRU closely resembling practices in place for that region during 1990-1995 in terms of manure and commercial fertilizer treatments and tillage.

For the AnnAGNPS, the DEM data, obtained from the USGS 30-m resolution, is also used as input into the TOPAZ model, a preprocessing model for establishing the basin hydrology. TOPAZ divides the basin into hydrologically defined subbasins and generates the stream network (cell configurations). In SWAT, however, the DEM values directly generate stream networks and delineate subbasins, based on the threshold values entered by the user for the reach length, allowing more flexibility in terms of the stream density networks and the number of sub-basins. In AnnAGNPS, the generated cells are the source of transport processes, of which the size and shape is based on user-defined critical source area (CSA) and minimum source channel length (MSCL) values. The larger the values of CSA and MSCL are, the larger the cell size, and the less dense the drainage network. Variable CSA and MSCL values were used in different parts of the German Brach subbasin in order to most accurately reflect the drainage and aggregated land use.

Weather data, common to both models, covered from 1990 to 1995 and was downloaded from a weather station in Easton, MD, adjacent to the watershed (reference?). Data included daily maximum and minimum temperatures, wind speed, daily precipitation, average daily dew point and sky cover. Sky cover was obtained indirectly from solar radiation.

Digital landuse for the German Branch was interpreted from 1990 aerial photography as described in Norton and Fisher (2000). In general, land use classifications were broken out into agriculture, forest, urban, and feedlots. There are numerous artificial drainage ditches in this watershed, therefore, where appropriate, surface drainage networks was digitized to the existing blue-line stream data layer developed from DEM.

4. Management Scenarios:

As stated previously, the calibration and validation for both models were performed using the 1990-1995 water quality database provided by Primrose et al. (1997). As such, management schedules reflect as closely as possible the management practices which were implemented at that time period. Determining those practices in time (planting/harvest/application dates) and space (where within the watershed) required extensive data collection including review of NASS documentation, and interviews with both extension agents and farmers. After this data was collected, typical management schedules were created and reviewed by the Choptank CEAP team for accuracy. Two major management schedules were identified. Both rotations reflect the fact that there was no cover crop program in place during that time period, so any small grain (e.g., barley, rye, winter wheat, etc.) was assumed to be fertilized in the fall and again in spring. The second rotation exists to represent the 30% production fields in the watershed which utilized conventional tillage. Poultry litter was applied to all of the fields in the model runs. Interviews with extension agents indicated that approximately 95% of farmers used some poultry litter on their fields in the German Branch. The nutrient content of the litter was estimated from literature data, specifically from the Maryland Extension Service. The same management and land use information were used in both models.

5. Model Calibration and Validation:

Monthly calibration data used were obtained from Primrose et al. (1997) and the Smithsonian Environmental Research Center (SERC) provided supplemental weekly data. These databases were used for calibration of both models.

For SWAT model, the initial calibration of model hydrology was done as an iterative process. SWAT simulates surface runoff, lateral flow, and ground water flow, total stream flow while observed data shows total stream flow. Even though, simulated total flow and observed total flow could be similar, simulated and observed surface flow and baseflow components may differ from one another. Such a difference may a profound effect on simulated nitrogen discharge from watershed as surface flow and groundwater flows will contain different concentrations of nitrate thereby affecting the load of nitrate to surface waters. Therefore, water balance in SWAT simulations was examined using literature data on watershed studies conducted in German branch (i.e., Jordan et al. 1997a). In this iterative process, the Curve Number (CN) values were adjusted until surface runoff corresponded to about half of the total stream flow as reported by Jordan et al. (1997b). The CN values were decreased by 10% from the default values to obtain reasonable surface flow predictions. While holding optimum CN value constant, OV_N (Manning's roughness coefficient value for overland flow), GWQMN (threshold depth of water in the shallow aquifer required for return flow to occur), ALPHA_BF (baseflow alpha factor), and ESCO (soil evaporation compensation factor) were changed. Then OV_N value was decreased from its default value of decree 0.1 to 0.01 and the ALPHA_BF value was decreased to 0.02 from its default value of 0.048.

6. Cover Crop Scenarios:

There was no cover crop program in place in the German Branch watershed during 1991 through 1995. Model simulation was conducted using calibrated parameters for 1991 to 1995 period. For SWAT model, the output from the HRUs was examined and the most effective and the least effective implementation scenarios were identified. Data in Table 1 show crop rotation #1 and cover crop scenarios used in both models. The calibrated models were used to evaluate the impact of cover crops on nutrient load reductions when 20, 40, 50, 60, and 70% of the agricultural land acreage under winter wheat was not fertilized and it was chemically killed in the spring.

Results and Discussion

1. Flow and nitrate calibrations:

Monthly and weekly flow calibration and validation was performed using the 1990-1995 databases. For AnnAGNPS, the baseflow estimates were derived from weekly calibration data using the lowest flows for each month over the calibration/validation period.

For the flow calibration, the following steps were taken: i) the CN values were adjusted until NS (Nash Sutcliff) coefficient of efficiency values did not increase any more; ii) the precipitation data file was adjusted for large storm events; iii) slope length values of stream segments were adjusted due to flat nature of the area and 30 m DEM resolution; iv) the Tc (time of concentration) values increased by as much as 30% in cells with natural riparian buffers.

For the nitrogen calibration, the date and application rates of poultry litter were adjusted. Using 1991-1995 climate data, AnnAGNPS was able to successfully predict monthly water discharge at the outlet of the German Branch with a Nash-Sutcliffe value of 0.49 and a R^2 value of 0.51 (Fig. 2). Event-based comparisons were not possible because the water quality data collected during 1991-1995 were weekly totals. Monthly total N loads were only calibrated to a Nash-Sutcliffe of 0.13, however trends were fairly well simulated though AnnAGNPS tended to over-predict N at the outlet (Fig. 3). Further adjustment of management practices will likely lessen the degree of over-prediction.

For SWAT flow and nitrate calibration, the same database (1990 – 1995) were used, but the order of time periods used for calibration and validation was reversed, that is; we used 1993-1995 portion of the database for calibration and the later, other three years (1990 through 1992), were used for validation. The reason was that 1993-1995 was relatively wet period and nitrate losses were higher than other three years (1990 -1992). Since the main goal of this study was to evaluate cover crop effect in German branch, calibration was elaborated for the period when nitrate losses were high.

The Nash-Sutcliffe coefficient of efficiency (NSE), coefficient of determination (R^2), and correlation coefficient (r) values were used to evaluate SWAT model performance. Fig. 4 shows observed and simulated monthly stream flow during calibration and validation periods. Graphical comparison shows that calibrated results are rather fair. The NSE, R^2, and r for calibration were 0.34, 0.50, and 0.70, respectively (Table 2). However, NSE, R^2, and r for validation period were -0.28, 0.12 and 0.35, respectively (Table 2). These values indicate a rather poor model performance in estimating monthly flows. The major discrepancy, however, occurred during the summer of 1992, where the SWAT model over-predicted the observed stream flow. It can be speculated that this is in part due to the fact that summer storms can be very isolated spatially. Given the quick response time of the German Branch, it is not unreasonable to assume that an isolated thunderstorm producing significant rain within the subbasin would not be recorded by the weather station, but result in runoff. Srinivasan et al. (1998) also experienced difficulties simulating streamflow in spring/summer months when the spatial variability of rainfall was high.

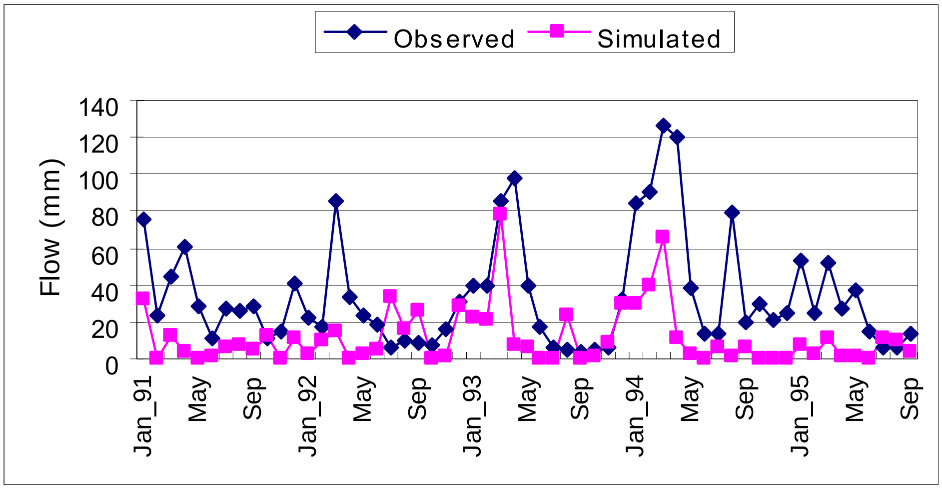


Figure 2. Observed and AnnAGNPS monthly simulated stream flow during calibration (1991-1992) and validation (1993-1995) periods.

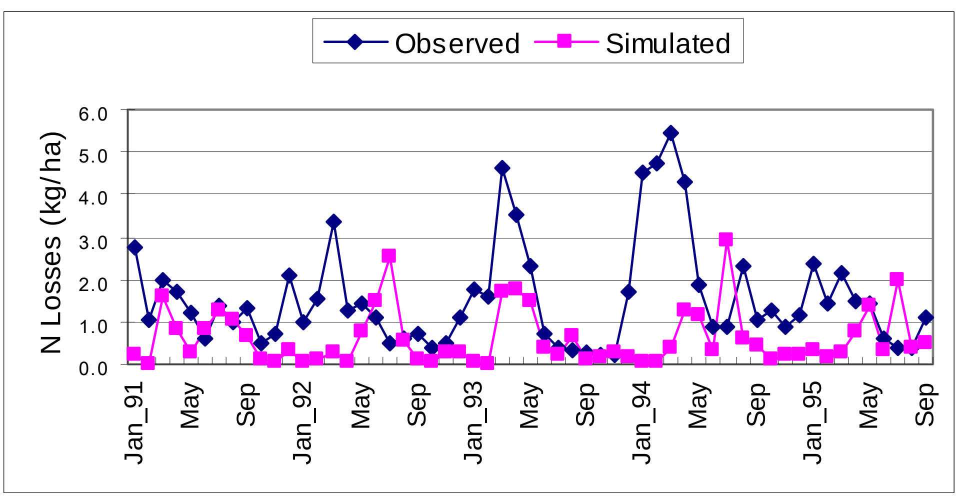
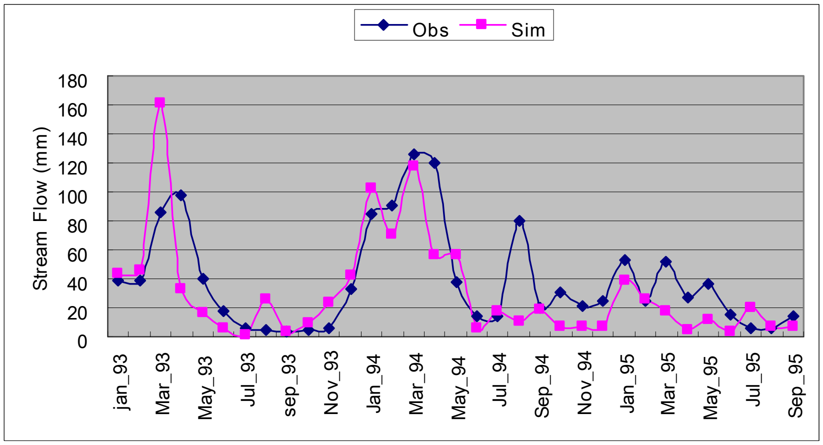
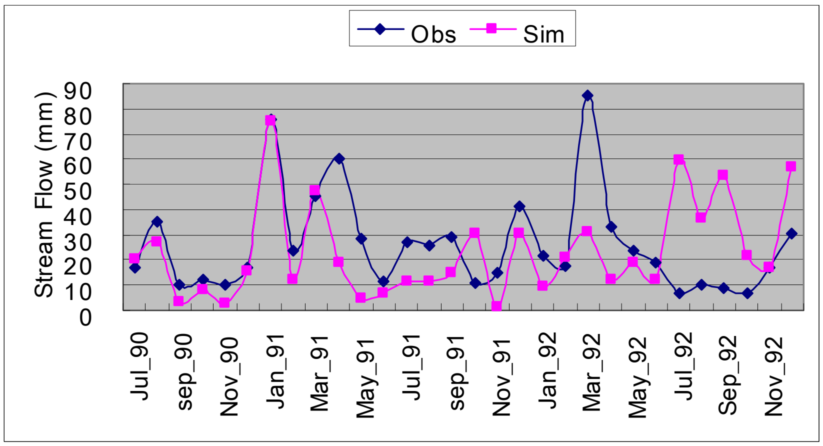


Figure 3. Observed and AnnAGNPS monthly nitrate losses during calibration (1991-1992) and validation (1993-1995) periods.



(a)



(b)

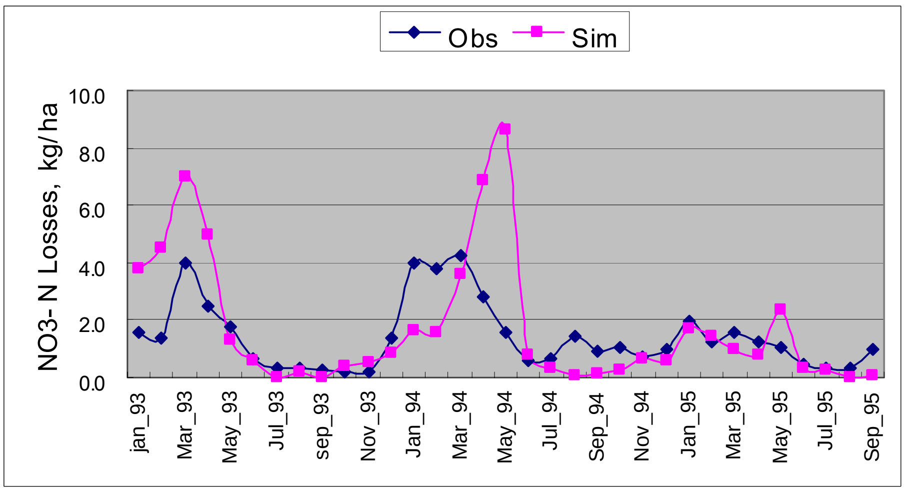
Figure 4. Observed and SWAT simulated monthly stream flow during calibration (a) and validation (b) periods.

Figure 5 shows the observed and SWAT simulated monthly nitrate losses during calibration and validation periods. The NSE, R^2, and r for calibration were -1.61, 0.33, and 0.58, respectively (Table 2). However, the NSE, R^2, and r for validation period were -1.61, 0.05 and 0.22, respectively (Table 2). Similar to the flow simulations, these values again indicate a rather poor model performance in estimating monthly nitrate losses. Over prediction of nitrate losses in summer of 1992 could also be explained by the over prediction of the stream flow. However, under-predicted nitrate losses observed in the summer of 1991 was difficult to explain. A source of error in the model predictions is undoubtedly the result of uncertainty in the spatial and temporal variability of management practices and associated input parameter values (Sohrabi et al., 2003). Quantifying this uncertainty would be a difficult task given the nature of the data. Some studies such as Santhi et al. (2001) suggest that SWAT performs well in predicting nutrient loads. But, some studies also revealed that monthly simulation of the nitrate losses by SWAT model was not satisfactory (Shirmohammadi et al., 2001). They reported major discrepancies between SWAT simulated and measured nitrate loads in the Warner Creek

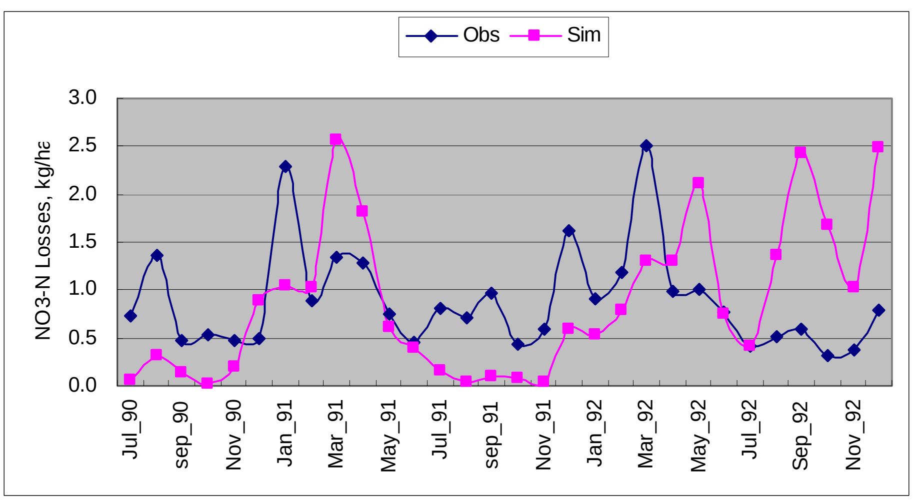
Watershed (3.5 Km^2 agricultural watershed), a fairly small watershed, in Maryland with a coefficient of determination of 0.27.

2. Cover Crop Scenarios:

The effect of cover crops on nutrient loads was evaluated with calibrated AnnAGNPS when 40% and 70% of the watershed area in winter wheat was not fertilized and the crop was chemically killed in the spring. In this scenario, 40% cover cropping resulted in little annual reduction in total N, however, increasing the area percentage of winter wheat to 70% yielded a dramatic decrease in total N at the watershed outlet (Fig. 6). This indicates that winter wheat can be beneficial cover crop with respect to reducing total N discharge at the outlet of watershed if participation by producers is high.



(a)



(b)

Figure 5. Observed and SWAT simulated monthly nitrate losses during calibration (a) and validation (b) periods.

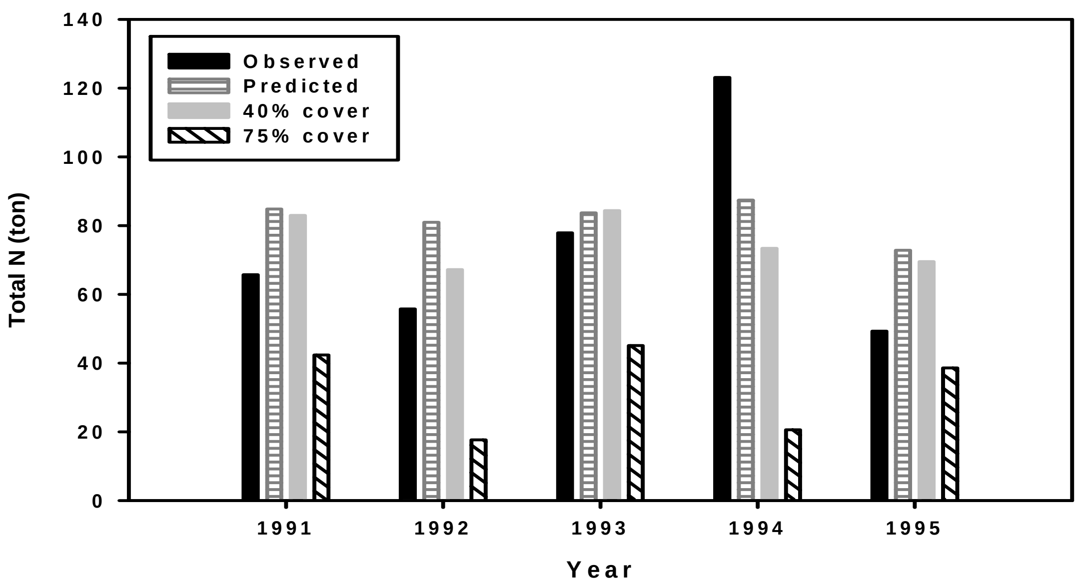


Figure 6. Cover crop effects on nitrate loads when 40% and 70% of the watershed area were planted to cover crops and not fertilized and the crop was chemically killed in the spring.

Similar procedure was also followed with SWAT model; however, additional cover crop scenarios were added. Cover crops were implemented in the model at 20, 40, 50, 60, and 70% of the agricultural land as a winter wheat cover crop receiving no fertilization and chemically killed in the spring. Instead of randomly assigning coverage, a targeted implementation approach was used. Data in Table 3 show how the HRUs are being chosen for the most and the least effective implementation scenarios. Annual average nitrate load simulation results of each HRU under baseline conditions were examined and ranked. The most effective approach for reducing nitrogen loads was cover crops implementation in the HRU with the highest baseline load first followed by the lower ranking HRUs.

Examining all the implementation scenarios, it was found that as the implementation area of cover crop increases up to 40%, annual nitrate losses were effectively reduced by 30% depending upon the simulation year. However, marginal reductions in annual nitrate loss occurred when cover crop implementation area reached beyond 50% of watershed area. Fig. 7 shows annual average cover crop effect on nitrate loss under the most effective and least effective scenarios. The reductions reported here represent five year average values. The simulation results showed that 30% of nitrate could be reduced if cover crops are implemented in up to 50% of the arable land in the watershed. On the contrary, only 5% reduction is expected when implementation is in the reversed order. The actual implementation of cover crops to the watershed would normally be done in a random fashion and reflects anticipated program participation. Therefore, the actual effect of nitrate reduction could be between 5 to 30% if cover crops are implemented at up to 50% of the total area of arable land in the watershed according to the simulation results using SWAT. The simulation results also suggest that a targeted approach is needed to achieve desirable level of nitrate reduction by cover crop BMPs.

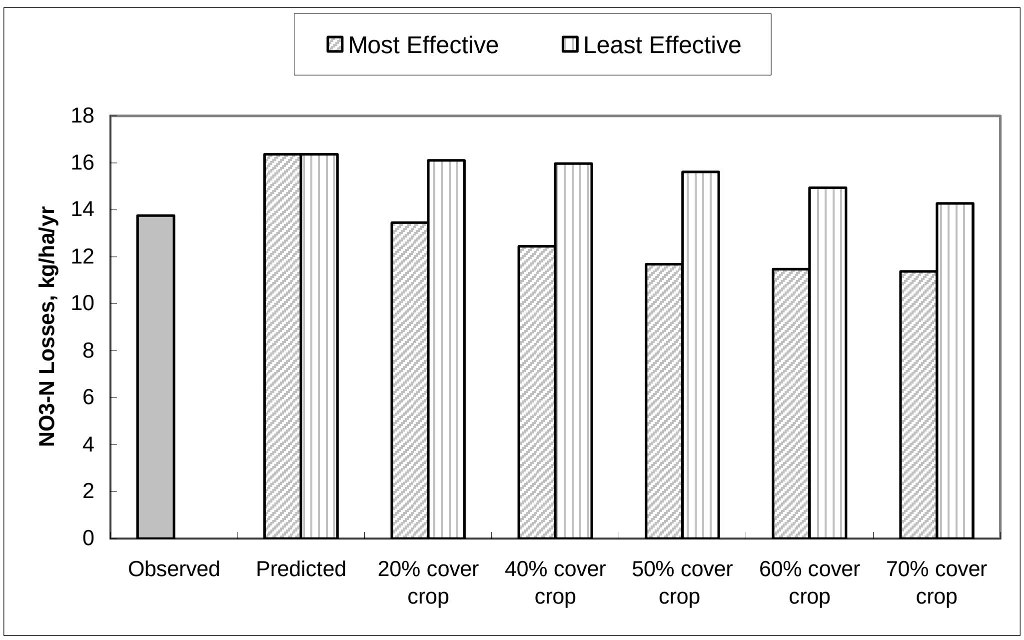


Figure 7. Annual average cover crop effect on nitrate losses under the most effective and least effective cover crops scenarios.

Conclusions

Model performance assessment conducted in this watershed showed that both models can be used to reasonably simulate the annual stream flow and nitrate loads within watersheds with characteristics of Coastal Plain agricultural landscape. AnnAGNPS was successfully calibrated and validated for flow in German Branch subwatershed with Nash-Sutcliffe values of 0.61 and 0.71 for total streamflow and nitrate loss, respectively. Nitrogen loads were calibrated to a

Nash-Sutcliffe of 0.51 from 1991 – 1993. While this calibration level is only slightly above an acceptable 0.5 value, further adjustments to the input parameters did not improve the calibration. Simulation of two different cover crop levels in the watershed revealed that a high level of cover crop implementation is needed (more than 40%) before any significant reductions in nitrate loads are observed in the German Branch watershed.

For the SWAT model, the NSE and r for stream flow calibration were 0.34 and 0.70 and for nitrate calibration were -1.61 and 0.58, respectively. These values indicate a rather poor model performance in estimating monthly flows. The major discrepancy, however, occurred during the summer of 1992, where the SWAT model over predicted the observed stream flow. It can be speculated that this is in part due to the fact that summer storms can be very isolated spatially. Given the quick response time of the German Branch, it is not unreasonable to assume that an isolated thunderstorm producing significant rain within the subbasin would not have been recorded by the weather station, but runoff was recorded at the watershed outlet.

SWAT simulation results showed that up to 30% of nitrate export could be reduced if cover crops are implemented on more then 50% of the arable land in the watershed, if the implementation is targeted to the most critical pollution areas of the watershed; the approach being from higher to lower sensitive areas. In these scenarios, the effect of additional incremental cover crop acreage resulted in marginal changes in nitrate reduction. The actual effect of a 50% cover crop implementation in reducing nitrate in this watershed using the approach of random participation is only expected to be between 5-30%. This model simulation also indicates that nitrogen loss reduction can be optimized with targeted implementation in those areas with the highest nitrogen loads. Therefore, SWAT can be viewed as the adequate and an acceptable tool for cover crop BMP evaluations for the Coastal Plain watersheds with similar characteristics of the German branch watershed.

Table 1. Crop rotation #1 and cover crop scenarios

Rotation 1 (Ag1): Corn, commodity wheat, double crop beans.	Cover crop scenario for Rotation 1 (Ag1)
April 12th poultry manure application; 2 T/A	April 2nd poultry manure application; 2 T/A
April 27th poultry manure application; 1 T/A	April 15th poultry manure application; 1 T/A
April 30th plant corn; no-till	April 27th plant corn; no-till
June 15th siddress 30% U.A.N.; 100 lbs/acre	June 14th siddress 30% U.A.N.; 100 lbs/acre
October 15th Corn harvest	October 8th Corn harvest
October 25th disk	October 18th broadcast plant winter wheat
October 30th poultry manure application; 1 T/A	
November 5th plant winter wheat	
March 5th 30% UAN 60 lbs N/A	April 30th chemically kill wheat
March 30th 30% UAN 60 lbs N/A	
June 10th harvest	May 20th plant double crop soybean; no till
June 15th plant double crop soybean; no till	November 15th soybean harvest
November 10th soybean harvest	November 11th Fallow
November 11th Fallow	

Table 2. Model evaluation indices.

		Calibration	Validation	Remark
Stream Flow, mm	NSE	0.34	-0.28	
	R^2	0.50	0.12	
	Correlation Coefficient	0.71	0.35	
	RMSE	27.9	21.5	
NO_3-N, kg/ha	NSE	-1.61	-1.61	
	R^2	0.33	0.05	
	Correlation Coefficient	0.58	0.22	
	RMSE	1.88	0.84	

Table 3. Selection of HRU for the most and the least effective implementation scenarios.

Most effective implemention of cover crop					Least effective implementation of cover crop				
Rank	HRU	N Losses (kg/ha)	Area (%) of Agricultural Land	Cumulative Area(%)	Rank	HRU	N Losses (kg/ha)	Area (%) of Agricultural Land	Cumulative Area(%)
1	27	40.2	0.80	0.8	1	92	8.7	0.85	0.9
2	11	40.0	3.26	4.1	2	96	9.1	2.13	3.0
3	13	40.0	5.00	9.1	3	110	9.8	2.52	5.5
4	36	39.9	2.03	11.1	4	75	9.9	0.97	6.5
5	88	30.5	1.18	12.3	5	68	11.0	1.36	7.8
6	8	29.4	0.79	13.1	6	79	11.0	0.71	8.5
7	74	29.4	1.65	14.7	7	44	11.4	0.54	9.1
8	4	25.8	1.21	15.9	8	28	11.4	0.55	9.6
9	35	25.8	0.73	16.6	9	12	11.5	3.12	12.8
10	60	25.8	0.06	16.7	10	84	11.5	0.28	13.0
11	10	25.8	4.14	20.8	11	18	11.5	0.07	13.1
12	85	25.8	0.28	21.1	12	21	11.5	1.51	14.6
13	114	25.7	3.84	25.0	13	3	11.5	0.98	15.6
14	61	25.7	0.05	25.0	14	46	11.5	0.93	16.6
15	22	25.7	3.26	28.3	15	55	11.7	1.08	17.6
16	99	25.7	0.61	28.9	16	89	11.8	0.85	18.5
17	107	25.7	7.34	36.2	17	51	11.9	1.05	19.5
18	109	25.7	2.02	38.2	18	33	11.9	1.73	21.3
19	65	25.6	0.59	38.8	19	29	11.9	1.19	22.5
20	66	25.6	0.21	39.0	20	53	12.0	1.61	24.1
21	39	25.5	0.31	39.4	21	111	12.5	2.46	26.5
22	69	25.5	0.81	40.2	22	94	12.5	0.61	27.1
25	40	25.5	0.57	40.7	25	117	12.9	0.01	27.2
26	19	25.5	0.11	40.8	26	101	13.9	0.59	27.7
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